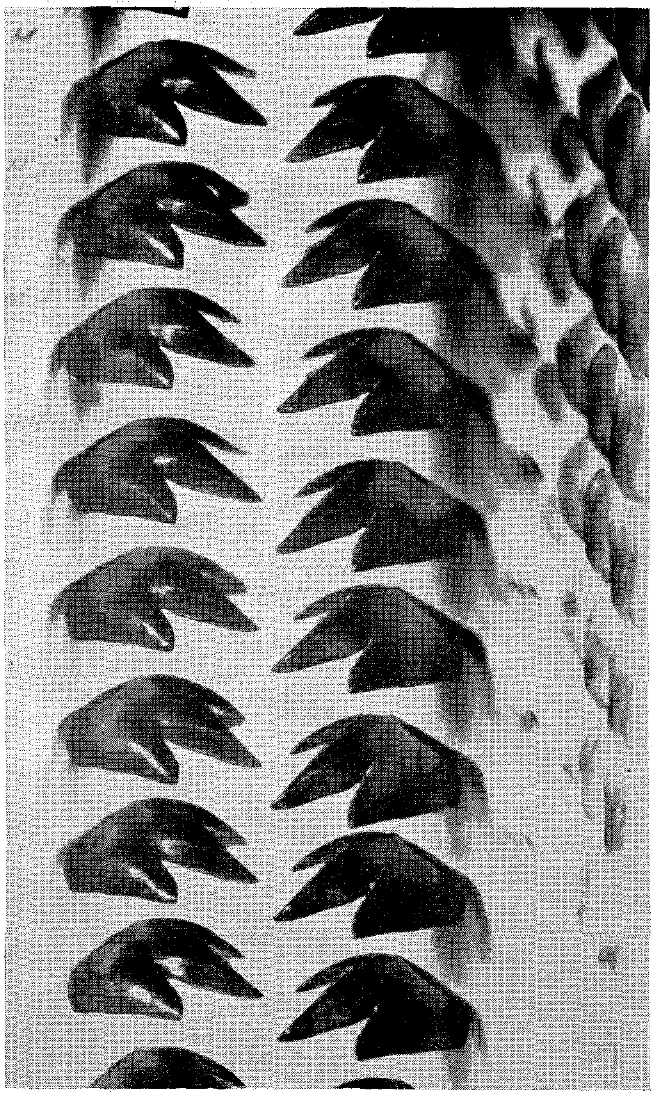


THE CASE OF THE IRON TEETH

Research on a slug-like sea creature called the chiton produces the first evidence that iron can be manufactured biologically.

Heinz A. Lowenstam, professor of paleoecology at Caltech, is a firm believer in simple observation. In fact, his idle observation of a tide pool in Bermuda has evolved into a new research project on evolutionary processes, resulting in the discovery of some new and unfamiliar minerals in sea animals.

In 1961 Dr. Lowenstam was in Bermuda gathering specimens of shelled creatures for environmental studies. One morning, as he gazed into a tide pool, he noticed deep gouge marks on the rocks in the bottom of the pool. It turned out they were made by a slug-like creature called a chiton, which scrapes algae from rocks with its teeth.

The marks were so deep, even in rocks as hard as limestone, that Dr. Lowenstam's curiosity led him to investigate further. He found that the chiton's teeth were capped with shiny black magnetite, a common and very pure form of iron ore. Salt water does not damage the teeth, and they are hard enough to scratch glass. The deep gouge marks are made when the chiton scrapes off the outer layer of rocks, scooping up the algae that are growing in the deeper layers underneath.

More extensive research on the chitons revealed that these creatures have existed on the earth for about 500 million years. They range from microscopic size to almost nine inches long, and are found from the polar regions to the tropics, and from shorelines to ocean depths of about 20,000 feet. One variety has been known to live for about 20 years. Although sightless, most chitons have strong homing instincts and return unerringly to the same location on the same rock. Since their teeth have been found to be magnetic, it is possible that they serve as some sort of biological compass.

The chiton has 70 teeth in two rows of 35 on each side, attached to a tongue-like structure. The teeth operate somewhat like a belt line – rolling, scraping, and drawing food back into the mouth simultaneously. Only four to six teeth emerge from the mouth at a time, and when teeth wear down, they are discarded and replaced from both rows as they move forward. This ability to manufacture

Heinz A. Lowenstam, professor of paleoecology, in his marine laboratory in Caltech's division of geological sciences.

more teeth to replace the ones that are worn down is the first evidence scientists have that iron can be manufactured biologically.

Dr. Lowenstam has now found other sea creatures containing iron compounds which are softer than the magnetite found in the chiton's teeth — such as the deep sea clams found as far down as 18,000 feet in waters around Antarctica; and limpets, which are primitive sea snails.

All of this evidence has led Dr. Lowenstam to question how iron is distributed in molluscs which have teeth, and what the evolutionary significance of the iron distribution may be.

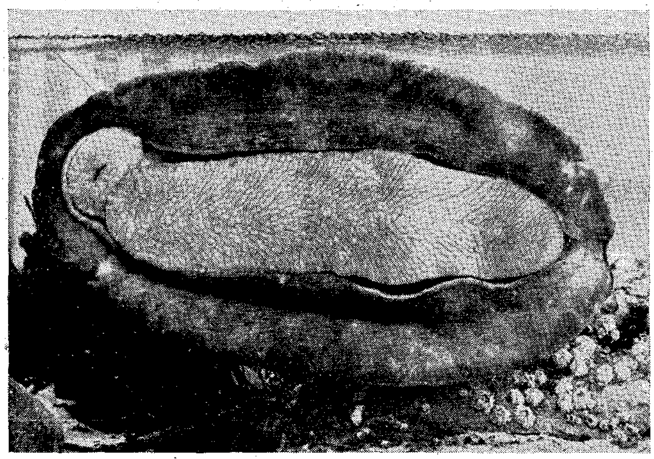
First of all, Dr. Lowenstam assumes that the chiton was in competition with other rasping organisms for algae, and in ages past, among other changes, a mutation occurred which developed harder teeth. Thus, the chiton could find food from the deeper layers of rock instead of just at the surface.

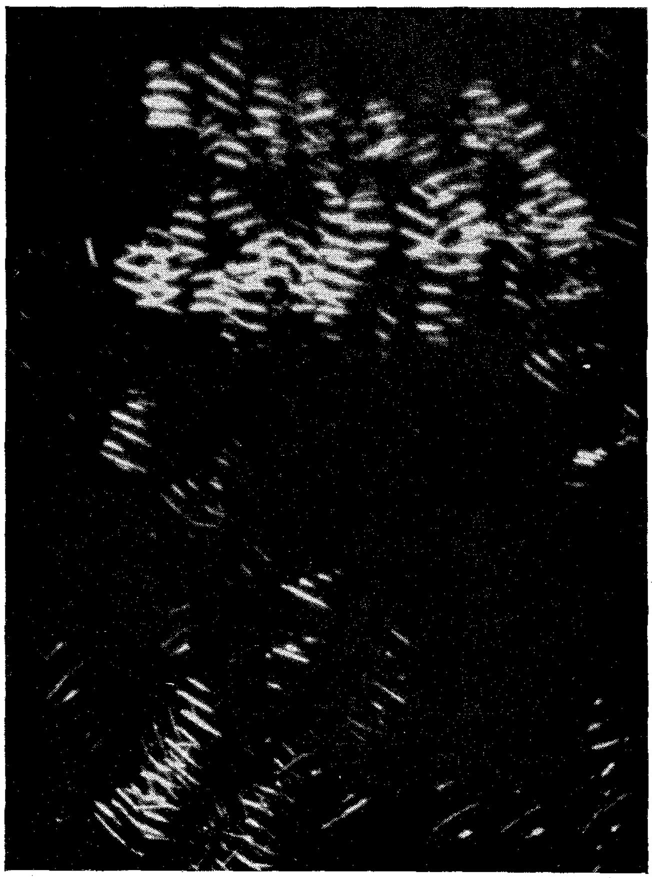
Using x-ray diffraction techniques, Dr. Lowenstam found that the tooth enamel from some chiton species corresponded with the mineral magnetite, while those from other chiton species contained some unidentified minerals, *plus* the magnetite. Some limpets showed a mineral remarkably like goethite — this being the first evidence that the mineral goethite is precipitated by marine invertebrates.

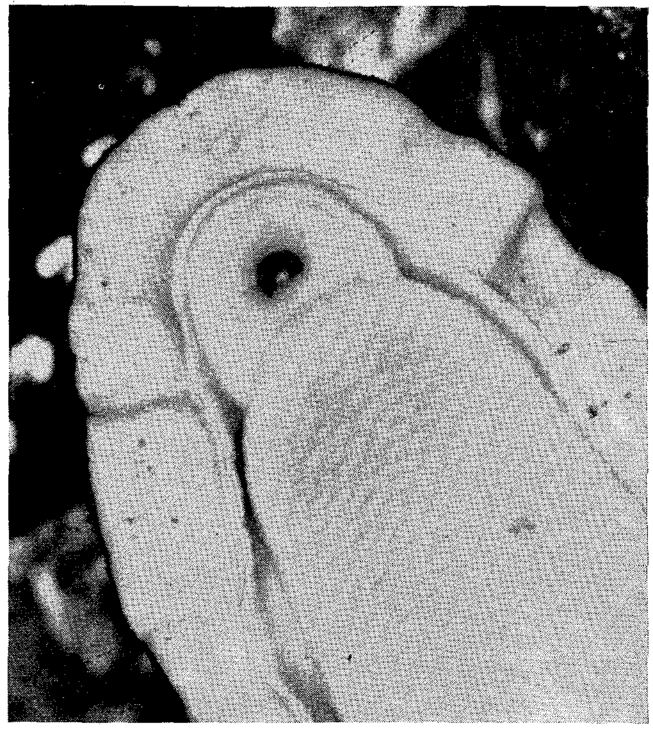
But how does the iron get on the teeth and is it really metabolized by organisms?

This question is being investigated by Michael Nesson, a graduate student in biology at Caltech, who is cooperating in the Lowenstam project. Mr. Nesson and Dr. Kenneth Towe, postdoctoral research fellow in geology, knew that there had to be an iron storage protein to develop the iron teeth. They eventually determined that this protein was ferratin — which had previously been found in only one invertebrate, a worm, although it is a common iron storage protein in all vertebrates, including man.

The compounds which form the iron could come from marine algae, which commonly enrich iron







Chitons move much like snails, creeping on one large foot, which adheres to rocks or pilings. The chiton above has opened its mouth to scrape algae from the aquarium wall with its iron teeth, leaving the deep gouge marks shown at left.

in the tissues of these sea creatures, and form the major part of the chiton's diet. The iron could also be derived from the dissolution of ingested sediment particles in the intestinal tracts of these animals. Dr. Lowenstam has in fact found the iron storage protein ferratin in the tissues surrounding the chiton's teeth.

One of the major points being investigated now is how the iron is transported through the whole system of the chiton before it becomes magnetite. Also, scientists are investigating many other sea animals to see if this same process is going on in them.

Sea water today contains, among other things, equal proportions of non-radioactive strontium, and calcium. Certain lower sea animals were believed to have the same proportions of these substances in their body chemistry. But, from the studies made so far, Dr. Lowenstam has discovered that, through an evolutionary period of about 300 million years, limpets have changed their fluid body chemistry. By a series of mutations, they have learned to progressively reject the strontium in their bodies and shells, thus becoming biochemically independent of the chemistry of their environment.

Dr. Lowenstam leaves next month for the Fiji Islands to collect fossils from late tertiary marine deposits. Preliminary studies of the shell chemistry of the sea creatures found there indicate that the deposits were laid down in deep, cold water about 50 million years ago.

He then goes to Palau in the Caroline Islands, 500 miles east of the Philippines, and 500 miles north of New Guinea, to find out what minerals various reef-building organisms precipitate to make reefs.

Dr. Lowenstam's research has been supported by the Shell Development Company and the Petroleum Research Fund of the American Chemical Society, and is being sponsored by the National Science Foundation.